INVESTIGATION IN THE SERIES OF CONDENSED HETEROAROMATIC SYSTEMS INCLUDING A THIOPHENE RING. COMMUNICATION 20.* METALLATION OF BENZO-[b]-NAPHTHO-[2,3-d]-THIOPHENE AND DESULFURIZATION OF ITS ALKYL DERIVATIVES

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It is known that furan [2], thiophene [3], benzo-[b]-thiophene [4], thieno-[2, 3-b]- and thieno-[3, 2-b]thiophenes [5] are readily metallated by n-butyllithium in the free α -position of the heteroaromatic ring. Dibenzofuran, dibenzothiophene and N-ethylcarbazole [6, 7] replace the hydrogen atom of the benzene ring closest to the heteroatom by a metal. The ease of metallation is determined by the value of the inductive effect of the heteroatom [8]. One of the generally accepted mechanisms of the metallation of heterocyclic systems consists of the initial coordination of the metal atom of the metallating agent with the unshared pair of electrons of the heteroatom, followed by removal of the hydrogen atom next to the heteroatom, with the aid of the anion of the metallating agent, and migration of the cation to this position.

We showed earlier [9] that in an attempt to metallate benzo-[b]-naphtho-[2, 3-d]-thiophene (I) with metallic lithium, elimination of a sulfur atom and the formation of β -phenylnaphthalene were observed. In this work we studied the effects of n-butyllithium on benzo-[b]-naphtho-[2, 3-d]-thiophene (I) and the possibility of using the organometallic compounds formed for the synthesis of various derivatives of this system.

The metallation of benzonaphthothiophene (I) by n-butyllithium in a mixture of benzene and ether at room temperature, in contrast to the action of metallic lithium, proceeds rather readily with a good yield. The benzonaphthothiophene (I) was produced by dehydrogenation with selenium of the readily available 7, 8, 9, 10-tetrahydrobenzo-[b]-naphtho-[2, 3, d]-thiophene [10].

The question of the site of attack of the metallating agent was a rather complex problem. On the basis of the considerations cited above, it might have been assumed that after the initial coordination of lithium at the sulfur atom, the attack would be directed to the hydrogen atoms in the 4-, 6-, or 7-positions of the benzonaphthothiophene (I). Since the hydrogen atom in the 7-position is farther from the heteroatom than the hydrogen in the 4- and 6-positions, we might have considered the insertion of a lithium atom in the 7position relatively improbable. We confirmed this experimentally - the corresponding derivatives, produced by direct metallation of (I) and by the action of a Grignard reagent on 7-keto-7, 8, 9, 10-tetrahydrobenzo-[b]-naphtho-[2, 3-d]-thiopene, followed by dehydration and dehydrogenation [9], proved different. As was noted above, the electronegativity of the heteroatom has an effect on the change in the acidity of the closest hydrogen atoms. Moreover, the coordination of the lithium atom with a sulfur atom increases the polarization of the closest C-H bonds [11] in the 4- and 6-positions of the benzonaphthothiophene (I), which should have an effect on the ability for removal of hydrogen atoms in these positions when they interact with the anion of the metallating agent. At the same time, since the C-H bond in the 4-position is apparently more polarized than that in the 6-position fin the latter case, the polarization of the C-H bond should be reduced under the influence of the fourth condensed aromatic ring, as a result of delocalization of the electron density in the naphthalene fragment of the benzonaphthothiophene (I), insertion of a lithium atom into the 4-position is more probable

*For communication 19, see [1].

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Kings (v, cm	(.															
							No.	of neig	ghboring	unsubstit	tuted hy	drogen a	toms of	the aror	natic rin	50
Compound	r#	φ (C -	-c)of nar	htha lene	ring, pl	ud	ΞH		[4]	14		HE		щ	HI	
	COOH	410 w 412 m	430 w	453 W	480 s 470 m	485 m	705 w 717 w	730 s 725 s		755 s 755 s	765 m 760 w	800 w	8 1 5 w	845 W	865 w 873 w	880 s 895 m
	CIII3 C3H7	410 w	430 w		477 m 477 m			730 s 730 s	745 m 745 m	755 m	765 m	785 s 790 m		850 m	880 s 880 s	
	CHs CsH7		425 s 420 s		465 w	495 w 500 w	705 w 700 m	738 s 732 s		765 s 763 s		786 m	815 m 810 m		860 w	875 s 880 s
s s	CH3 C3H7	410 m	420 m 430 w	435 w	480 w		702 m 702 s	732 s	745 w	763 s 765 m		782 m 782 m			865 m 860 w	875 s
	CH ₃	420 w			485 W	507 w	695 s	- <u> </u>	750 s	768 s		787 in		823 m		
	CII3		435 w		480 s		702 s			765 m		785 s	ш 708	818 s	865 s	
*For method of pr †In a mixture with	oduction n partia	n and co 11y hydr	mstants, ogenated	see [9]. I m-toly	, Inaphtha	lene.			•							

TABLE 1. Nonplanar Deformational Vibrations of C-C of the Naphthalene Ring and C-H of Aromatic Pinne I_1

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Therefore, we can assume that under the action of n-butyllithium on (I), followed by treatment of the organolithium compound with solid CO_2 , chiefly benzo-[b]-naphtho-[2,3-d]-thiophene-4-carboxylic acid (IIa) is formed, while the treatment with dimethyl sulfate or propyl chloride yields 4-methyl- or 4-propylbenzo-[b]-naphtho-[2,3-d]-thiophene (IIb, IIc), respectively



The IR spectra of compounds (IIa-c) (Table 1) are identical in the region of $700-900 \text{ cm}^{-1}$, characteristic of deformational out-of-plane C-H vibrations of the aromatic ring. Their spectra contain bands characteristic of four hydrogen atoms in a row (730, 760 cm⁻¹), three neighboring hydrogen atoms (790 cm⁻¹), and single isolated hydrogen atoms (880 cm⁻¹) [12]. We should also note the band in the region of $460-480 \text{ cm}^{-1}$, which belongs to the nonplanar deformational vibrations of the skeleton of the naphthalene ring ("+" denotes displacement of carbon atoms beyond the plane of the naphthalene ring; o denotes displacement in the opposite direction) [13-15].



The band is intense in naphthalene (472 cm⁻¹), β -alkylnaphthalene (469 cm⁻¹), β -phenylnaphthalene(480 cm⁻¹), 2,3-, 2,6-, and 2,7-dimethylnaphthalene (469, 464, and 467 cm⁻¹, respectively) [16], i.e., in the cases when there is no substituent in the 4- or 5-positions of the naphthalene ring. In our case the absorption in this region proved extremely useful for determining the position of the substituent in the benzonaphthothiophene (I). Since the band 480 cm⁻¹ is present both in the spectrum of benzonaphthothiophene itself (I) and in the spectra of its derivatives, produced by direct metallation of (I), namely (IIa) 470 and 485 cm⁻¹, (IIb) 477 cm⁻¹, and (IIc) 477 cm⁻¹, this can still serve as a confirmation of our hypothesis of the insertion of a lithium atom into the 4-position of benzonaphthothiophene (I). We should mention that in the case when the substituent is in the naphthalene fragment of benzonaphthothiophene (III), instead of the band in the region of 460-480 cm⁻¹, a band appears in the region of 410-430 cm⁻¹.



To confirm our conclusion drawn on the site of insertion of the substituent during the reaction of metallation of (I), we decided to use the desulfurization reaction, which was used earlier in a series of condensed thiophene-containing systems (see, for example, [9, 17-19]). It was found that in alkyl derivatives of benzonaphthothiophene (I), together with desulfurization, there is also a partial hydrogenation of the alkylphenylnaphthalenes formed. We should mention that hydrogenation in the process of desulfurization of polycondensed thiophene-containing systems was observed in our earlier work [9] and has also been noted in [19]. The hypothesis advanced in [19], that this is associated with the use of active Raney nickel, in our opinion, is insufficiently substantiated, since we also obtained analogous results using degasified [20] Raney nickel





When the alkyl group is in the naphthalene fragment of β -phenylnaphthalene (R = H, R' = CH₃), we succeeded in producing 5-methyl-2-phenylnaphthalene (IVa) by dehydrogenation. If, however, the alkyl substituent is in the phenyl ring of β -phenylnaphthalene (IVb), all our attempts at dehydrogenation (both with Se

and with Pd/C) proved unsuccessful – a mixture of m-tolylnaphthalene with partially hydrogenated m-tolyl-naphthalene was obtained.

In our opinion, an unambiguous confirmation of the insertion of the substituent in the 4-position of benzonaphthothiophene (I) during the process of metallation is the formation of the quinone (VII) in the oxidation of 4-methylbenzo-[b]-naphtho-[2, 3-d]-thiophene (IIb) with chromic anhydride; the product proved identical to the compound produced independently, by acylation of 7-methylbenzo-[b]-thiophene (V) with phthalic anhydride, followed by cyclization of the acylation product (VI) (data of elementary and gas-liquid chromatographic analysis, absence of depression of the melting point of a mixed sample, coincidence of IR spectra)



At the same time, the quinone (VIII), produced by oxidation of 7-methylbenzo-[b]-naphtho-[2,3-d]-thiophene (IIIa) [9] differs from the quinone (VII) in melting point and IR spectra



EXPERIMENTAL METHOD

The IR spectra were obtained on a UR-20 spectrometer; pressing with KBr.

<u>Benzo-[b]-naphtho-[2,3-d]-thiophene-4-carboxylic Acid (IIa).</u> A 2 g portion of (I) (the constants and method of production were cited in [9]) and 50 ml of a mixture (1:1) of benzene (free of thiophene) and abs. ether were loaded into a 200 ml bottle with glass balls; air was displaced with a stream of dry N₂, and a freshly prepared ether solution of 0.55 g n-butyllithium was added. After 6 h of shaking at room temperature, a light-brown color of the mixture appears, which then turns into a reddish-brown. After this, the mixture was shaken for another 38 h, then treated with dry ice and water. The solution was filtered off (30 mg of insoluble precipitate was removed), the filtrate acidified with 10% HCl, the residue filtered off, dried, and recrystallized from glacial CH₃COOH. We obtained 1.2 g (yield 51%) of (IIa), yellow color, mp. 262-264°. Found: C 73.38; H 3.59; S 11.53%. C₁₇H₁₀O₂S. Calculated: C 73.36; H 3.62; S 11.52%. Under the action of 2 eq. of n-butyllithium, the monoacid (IIa) with mp. 262-264° is also formed.

<u>4-Methylbenzo-[b]-naphtho-[2,3,-d]-thiophene (IIb).</u> Analogously, a mixture of a solution of 2 g (I) and an ether solution of 0.55 g n-butyllithium were shaken at room temperature for 41 h (after 4 h of shaking, the solution becomes brownish). Then the bottle was equipped with a two-horned adaptor, into one end of which a dropping funnel was inserted, while a reflux condenser was inserted into the other, and 1.2 g of dimethyl sulfate was added to the mixture with shaking. The mixture was heated for 2h at 35°, then, after 1 h of standing at room temperature, treated with water. The aqueous layer was extracted with ether, the combined ether extracts washed with a 5% solution of NaOH, with water to a neutral pH, and dried with anhydrous Na_2SO_4 . After removal of the solvent, the crystallized precipitate was dissolved in a mixture (1:4) of benzene and petroleum ether (bp. 40-70°), and the solution was passed through a column with AI_2O_3 . The solvent was distilled off, and the residue recrystallized from alcohol. We obtained 1.4 g (yield 70%) (IIb), mp. 192.5-193°. Found: C 82.22; H 4.72; S 13.05%; mol. wt. 246.7. $C_{17}H_{12}S$. Calculated: C 82.22; H 4.87; S 12.91%; mol. wt. 248.18.

<u>4-Propylbenzo-[b]-naphtho-[2,3-d]-thiophene (IIc)</u>. With analogous treatment of 2 g (I) (the mixture was shaken for 42 h at 20°, then heated for 3 h at 40°), followed by addition of 0.8 g propyl chloride at 20° and

heating at 40° for 2 h, 1.1 g (yield 47%) of (IIc) was obtained, mp. 137-138° (from alcohol). Found: C 82.78; H 5.79; S 11.59% mol. wt. 272.2. $C_{19}H_{16}S$. Calculated: C 82.72; H 5.50; S 11.45%; mol. wt. 276.24.

Desulfurization of 7-Methylbenzo-[b]-naphtho-[2, 3-d]-thiophene (IIIa). To a solution of 1 g (IIIa) (produced according to [9]) in 70 ml of xylene, we added 10 g of Raney nickel with mixing. The mixture was heated for 10 h, and after a negative test for sulfur with sodium nitroprusside, the catalyst was filtered off and washed thoroughly with hot xylene. The combined filtrates were evaporated under vacuum, the residue dissolved in petroleum ether (bp. 40-70°), and the solution passed through a column with AI_2O_3 . We obtained 0.65 g of an oily substance. Found: C 91.80; H 7.83%. $C_{17}H_{18}$. Calculated: C 91.89; H 8.10%. A mixture of 0.6 g of the product obtained and 0.5 g of powdered selenium was heated for 6 h at 270-285°, then extracted with benzene, the benzene distilled off, the residue dissolved in petroleum ether, and the solution passed through a column with AI_2O_3 . We obtained 0.52 g (yield 56%) of 5-methyl-2-phenylnaphthalene (IVa), mp. 105°. Found: C 93.66; H 6.61%. $C_{17}H_{14}$. Calculated: C 93.57; H 6.42%.

Desulfurization of 4-Methylbenzo-[b]-naphtho-2, 3-d]-thiophene (IIb). Analogously, a mixture of 1.8 g (IIb), 10 g Raney nickel, and 60 ml abs. alcohol was boiled for 8 h, then another 2 g of Raney nickel added, and heating continued for another 2 h. After treatment, 1.5 g of an oily substance was obtained. Found: C 91.00; H 8.98%. $C_{17}H_{20}$. Calculated: C 91.07; H 8.93%. The substance was redistilled, collecting the fraction with bp. 168-173° (3 mm). Found: C 91.95; H 8.21%. $C_{17}H_{18}$. Calculated: C 91.89; H 8.10%. A mixture of 0.6 g of the product obtained and 0.3 g of 30% Pd/C was heated for 10 h at 170-180° in a stream of dry N₂, then extracted with benzene, and the solution passed through a column with Al₂O₃. After the solvent was distilled off, an oily substance was obtained. Found: C 92.40; H 7.10%. $C_{17}H_{16}$. Calculated: C 92.72; H 7.22%. According to the data of gas-liquid chromatographic analysis and the IR spectrum, this substance is apparently a mixture of m-tolylnaphthalene (IVb) and partially hydrogenated m-tolylnaphthalene. Attempts to use degasified Raney nickel [20] to eliminate hydrogenation of the desulfurization products proved unsuccessful.

<u>Oxidation of 7-Methylbenzo-[b]-naphtho-[2,3-d]-thiophene (IIIa).</u> A mixture of 0.6 g CrO₃, 2 ml CH₃COOH, and several drops of water was heated until the CrO₃ dissolved, then 0.2 g (IIa) in 13 ml of CH₃COOH was added in portions. The mixture was left overnight, then diluted with water and cooled. We obtained 0.12 g of 7-methyl-6,11-dioxo-6, 11-dihydrobenzo-[b]-naphtho-[2,3-d]-thiophene (VIII), mp. 194-195° (from benzene and sublimation under vacuum). Found: C 73.30; H 3.87; S 11.54%. C₁₇H₁₀O₂S. Calculated: C 73.34; H 3.64; S 11.52%. 4-Methylbenzo-[b]-naphtho-[2,3-d]-thiophene (IIb) was oxidized analogously. 4-Methyl-6,11-dioxo-6,11-dihydrobenzo-[b]-naphtho-[2,3-d]-thiophene (VII) was obtained, mp. 225-225.5° (after two recrystallizations from CH₃COOH). Found: C 73.40; H 4.14; S 11.40%. C₁₇H₁₀O₂S. Calculated: C 73.34; H 3.64; S 11.15%.

<u>o-3-(7-Methylbenzothenoyl)benzoic Acid (VI)</u>. To a mixture of 10 g 7-methylbenzo-[b]-thiophene (V) [produced analogously to [21], bp. 111.5-112° (16 mm), n_D^{21} 1.6200; according to the data of [22]: bp. 112° (16 mm)], 16.5 g of phthalic anhydride and 60 ml of nitrobenzene, 35 g of AlCl₃ was added over a period of 30 min at 0-5°. The mixture was mixed at 20° for 12 h and left overnight. Then it was treated with a mixture of ice and HCl, the solvent steam distilled off, the reaction product converted to the Na salt, the solution obtained acidified with HCl, and the precipitate removed and dried. We obtained 3.1 g (VI), mp. ~ 240°. Found: C 69.00; H 4.50%. C₁₇H₁₂O₃S. Calculated: C 68.91; H 4.05%. Ethyl ester, mp. 99-101° (CH₃OH). Found: C 70.36; H 5.04%. C₁₉H₁₆O₃S. Calculated: C 70.35; H 4.97%.

<u>4-Methyl-6, 11-dioxo-6, 11-dihydrobenzo-[b]-paphtho-[2, 3-d]-thiophene (VII)</u>. A mixture of 3 g (VI), 2.38 g SOCl₂, 40 ml abs. ether, and four drops of pyridine was heated on a water bath for 3 h and left overnight. The ether and excess SOCl₂ were distilled under water-jet pump vacuum on a water bath, and the residue dissolved in chlorobenzene, and 8 g AlCl₃ added to the solution. After 6 h the mixture was treated with ice and HCl. We obtained 0.45 g (VII), mp. 224-225° (from CH₃COOH and sublimation under vacuum), which was identical with (VII), produced by oxidation of (IIb) with chromic anhydride (absence of depression of the melting point of a mixed sample, coincidence of IR spectra).

CONCLUSIONS

1. Under the action of n-butyllithium on benzo-[b]-naphtho-[2, 3-d]-thiophene (I), the lithium atom is inserted in the 4-position of the benzonaphthothiophene system.

2. In the desulfurization of 4- and 7-alkyl derivatives of benzonaphthothiophene (I) by Rancy nickel, together with desulfurization there is a partial hydrogenation of the alkyl derivatives of β -phenylnaphthalene formed. 3. On the basis of a comparative study of the IR spectra of 4- and 7-alkyl derivatives of benzonaphthothiophene (I) and alkyl derivatives of naphthalenes, general principles in the vibrational spectra of these systems were found, which permitted a reliable confirmation of the position of the substituent in 4- and 7alkyl derivatives of (I).

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